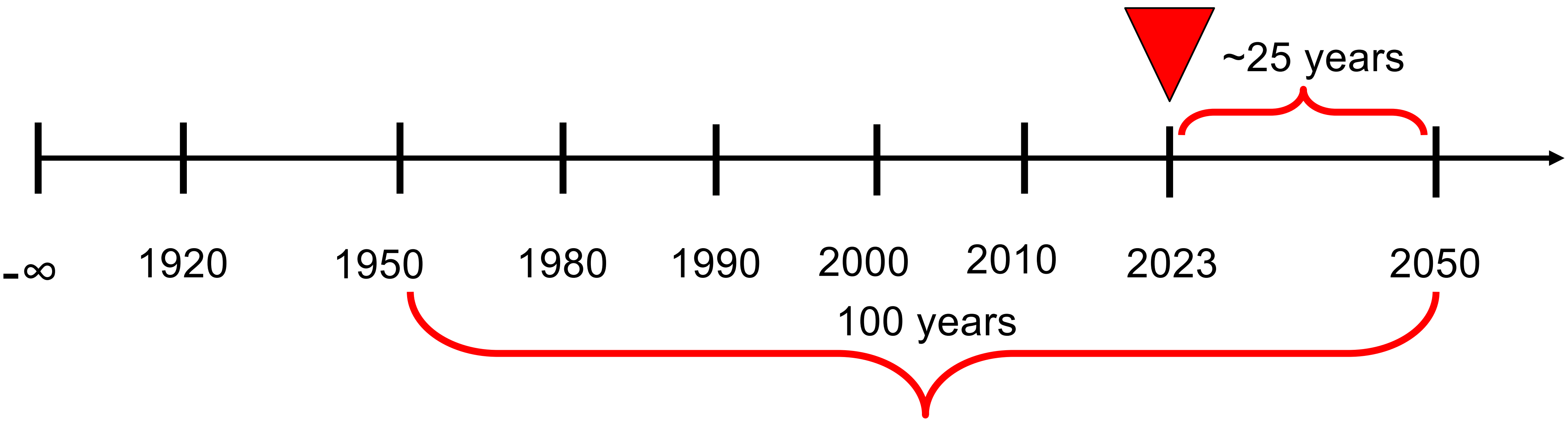
One Hundred Years of Robotics, Where Shall We Arrive?

Paolo Fiorini
Needleye Robotics Srl, & Universita' di Verona

Why One Hundred Years?



What will we do in 25 years?

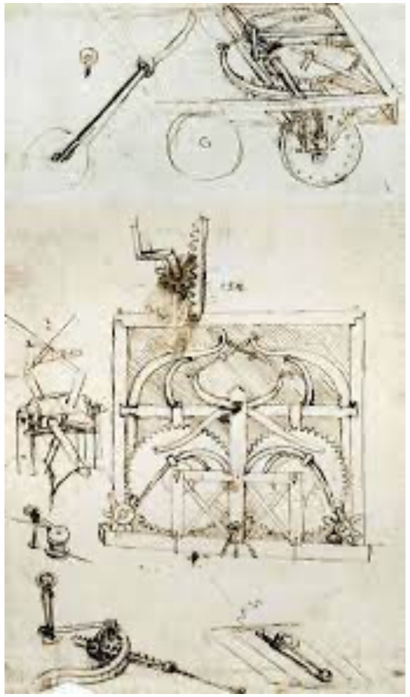
Summary

- Past – we don't care
- Present – we know
- Future – we don't know

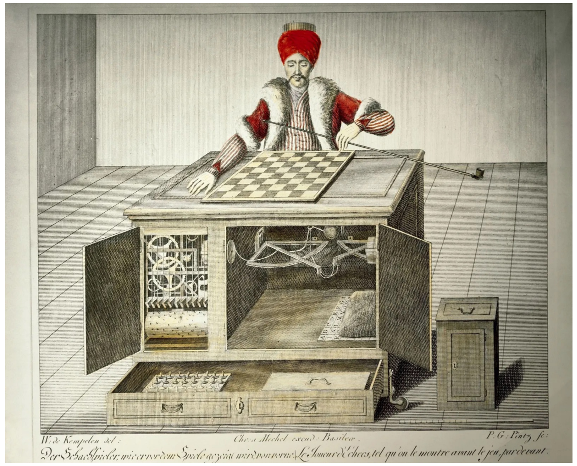
Perhaps this talk will not have much new information ☺

The Artificial Human

The “karakuri ningyō” are human automata built in the 17th century in Japan

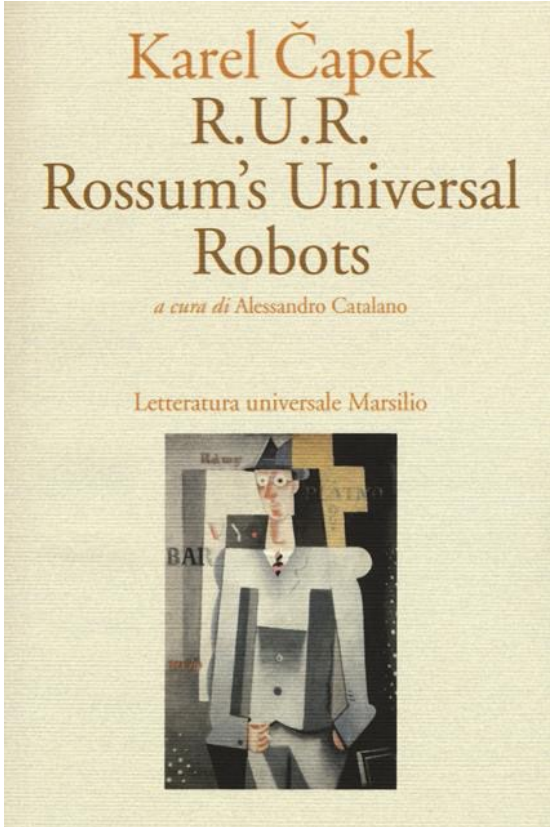


In 1495 Leonardo drew the plans for a mechanical knight

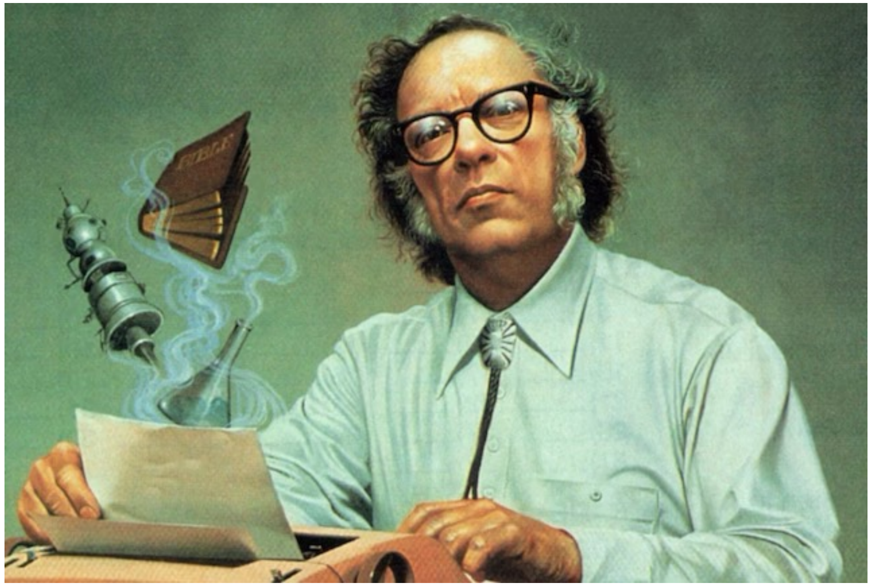


The “Mechanical Turk” developed in 1770 by the Hungarian inventor Kempelen Farkas

The Name is Given

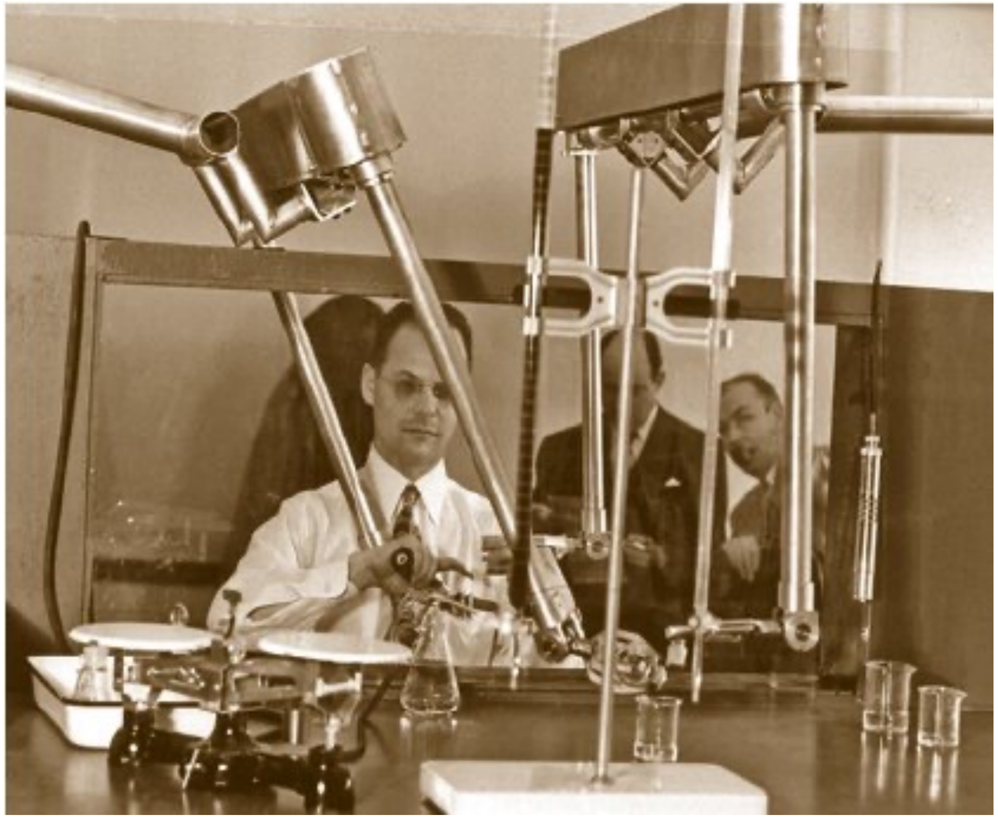


Karel Capek first introduced the word "robot" (forced labor in Czech) in the 1920s

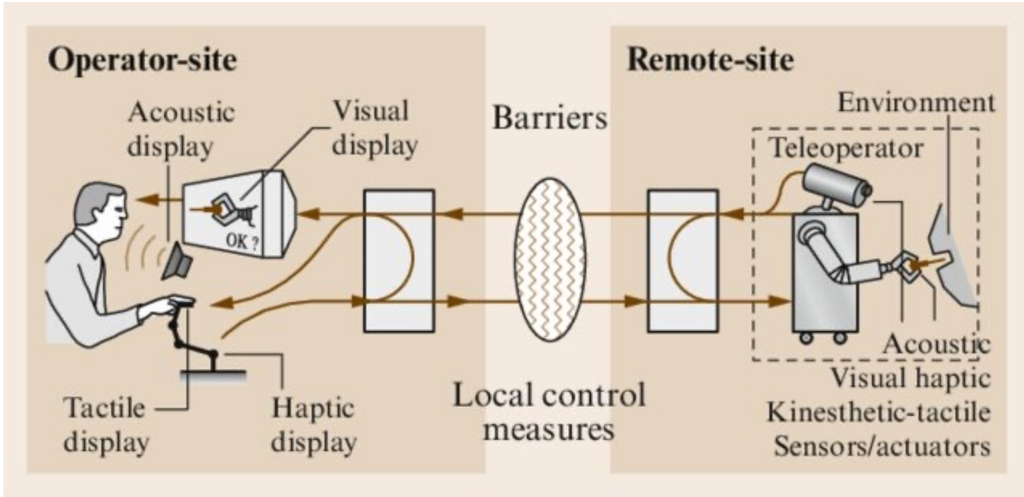


Isaac Asimov introduced the concept of "robotics" in 1940's

Where It All Started

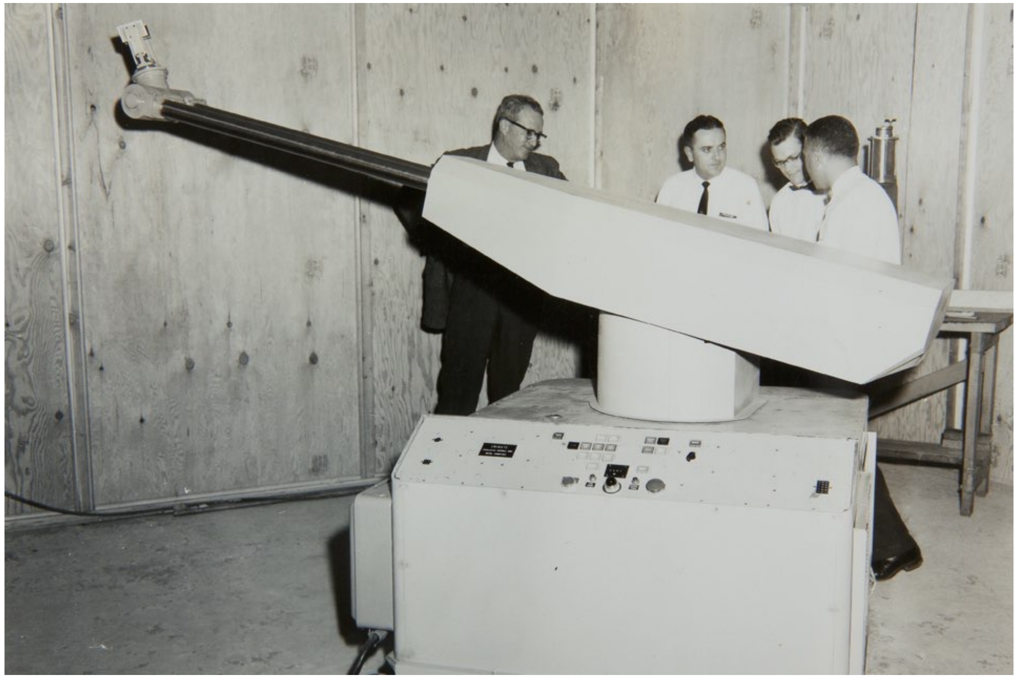


Raymond Goertz
in the 1940s at the
Argonne National Laboratory



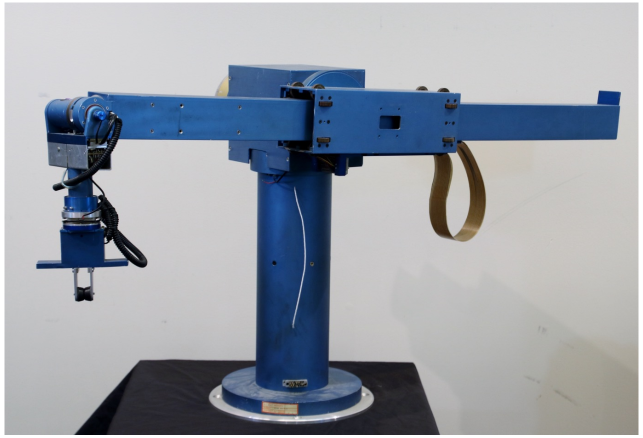
Programmed Articulated Transfer Device

- **In 1954, George Devol** replaced the master device of the teleoperator with the computer control of a CNC, machine and called this device a "programmed articulated transfer device." for which he filed a patent.
- The patent rights were bought by a Columbia University student, **Joseph Engelberger, who founded a company called Unimation in 1956**.
- In **1960, the first Unimation ROBOT** was demonstrated, and the first installation was done the following year at a General Motors plant



Stanford Arm -> Vic Arm -> Unimation

The Stanford arm was designed in 1969 by Victor Scheinman at the Stanford Artificial Intelligence Lab (SAIL).



In **1973**, Victor Scheinman developed the Vicarm, which was sold in 1977 to Unimation

Theory and Applications in the 70's

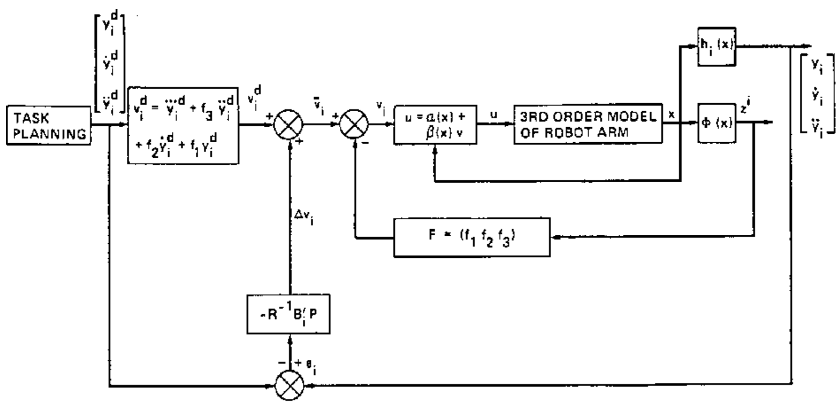
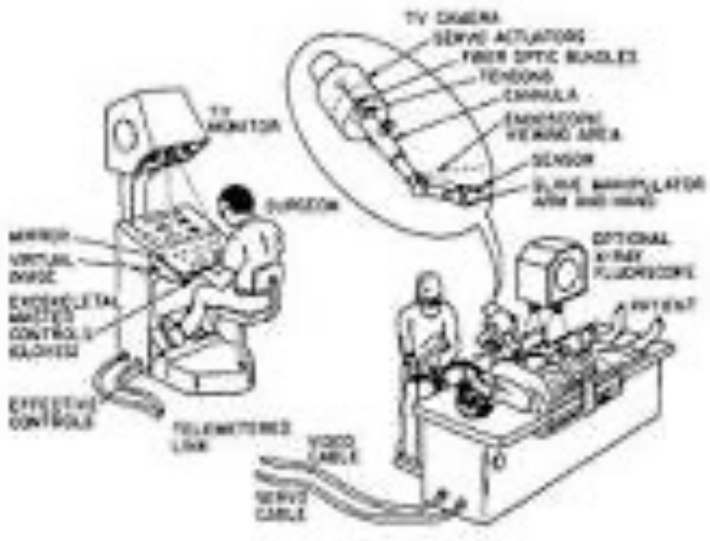


Fig. 1. Control configuration for a linearized subsystem (equal to a task space variable).

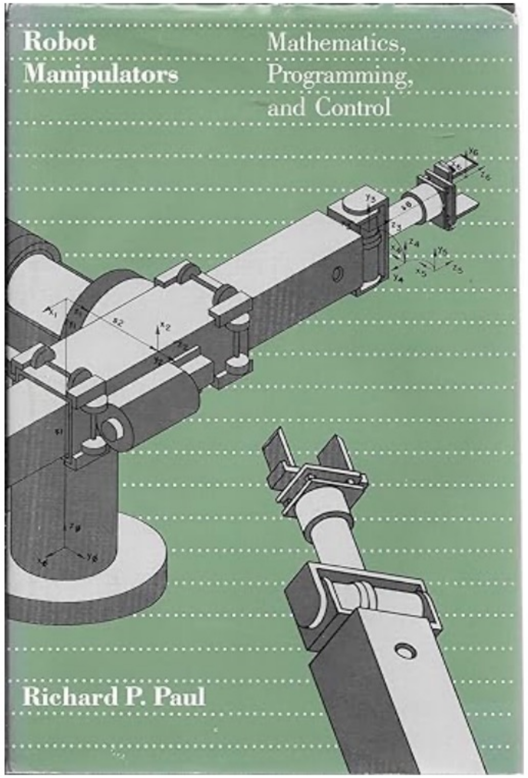
First dynamic model of a robot by Antal Bejczy at Caltech NASA-JPL

First anthropomorphic industrial robot (T3) by Cincinnati Milacron



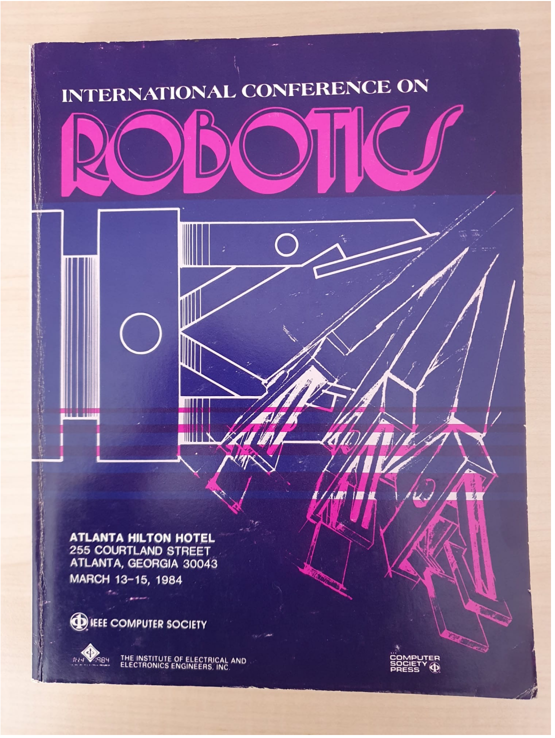
The idea of robotic surgery was probably proposed by NASA

Book and Safety-Critical Use in the 80's



in **1984**, a team from Memorial Medical Center in Long Beach and hold and NASA-JPL

World Robotics in 1980's

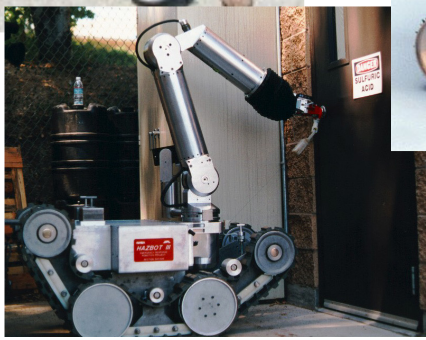


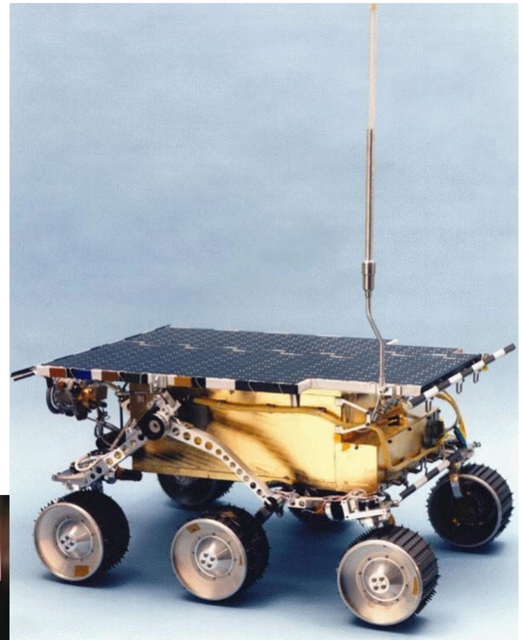
First IEEE ICRA 1984 (450 people)

NATO workshop @ Salo' 1988

Robotics @JPL in 1990

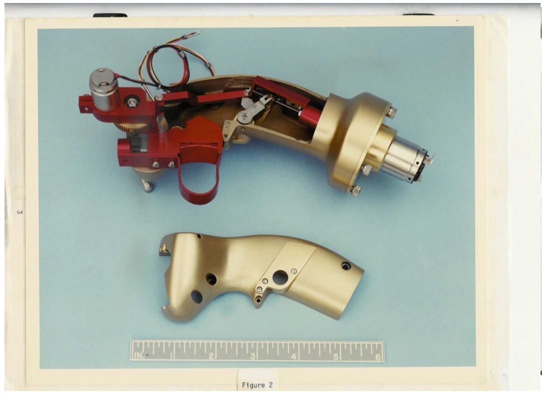
Advanced Teleoperation Lab

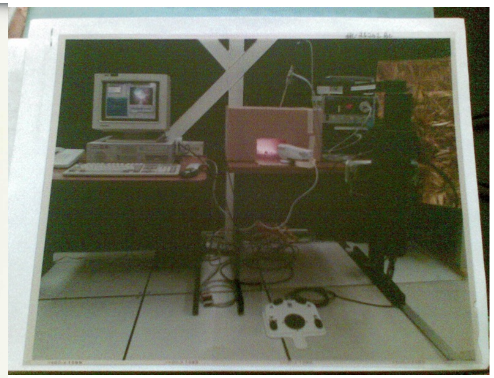




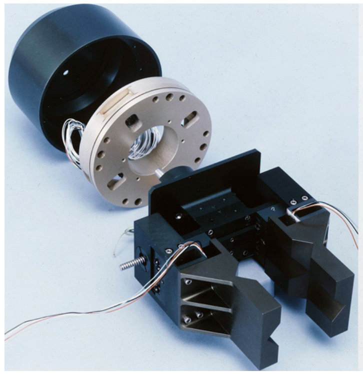
Mobility Lab

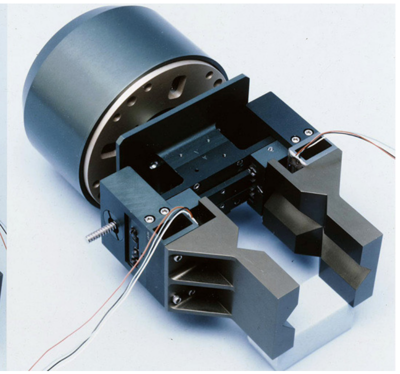
Robotics @JPL : Teleop & Haptics





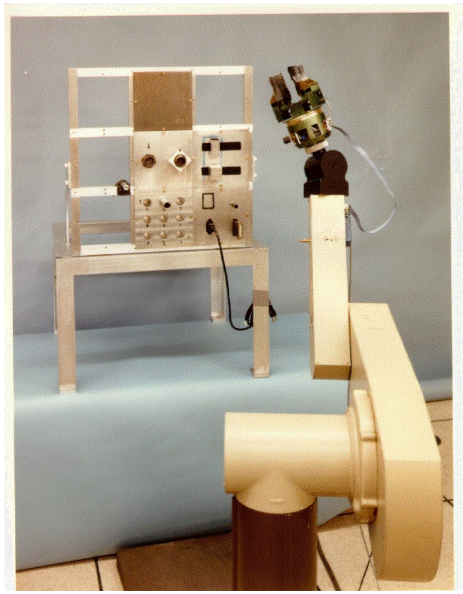
1986-1990





1993

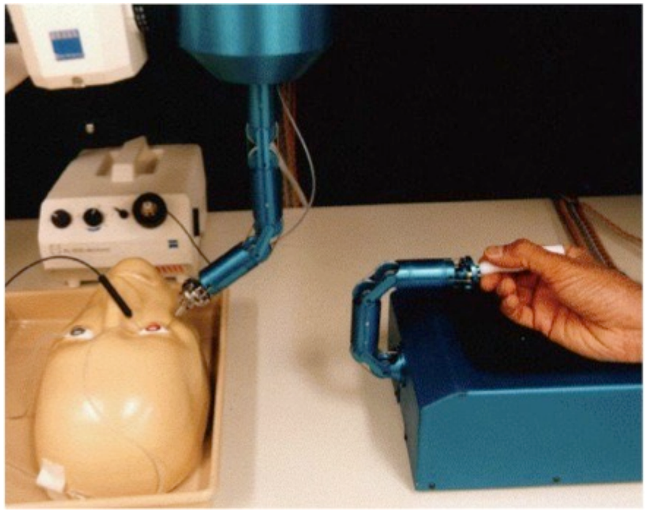
1990



1994

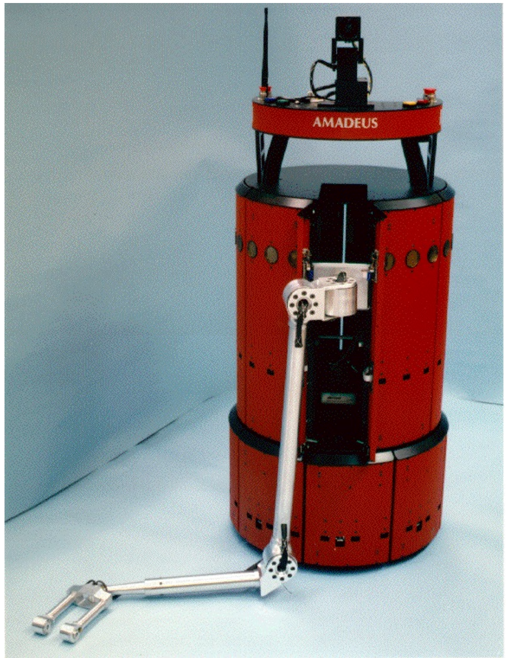
Robotics @JPL : Teleop & Haptics

Robotics @JPL: Medical



1995

1998

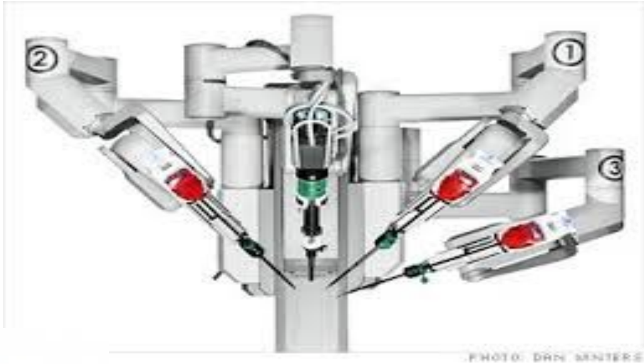


1999

Robotics @JPL : Medical

The Development of Surgical Robots

Richard Satava,
UW - DARPA



Intuitive Surgical
Da Vinci robot

Antal Bejczy,
NASA - JPL

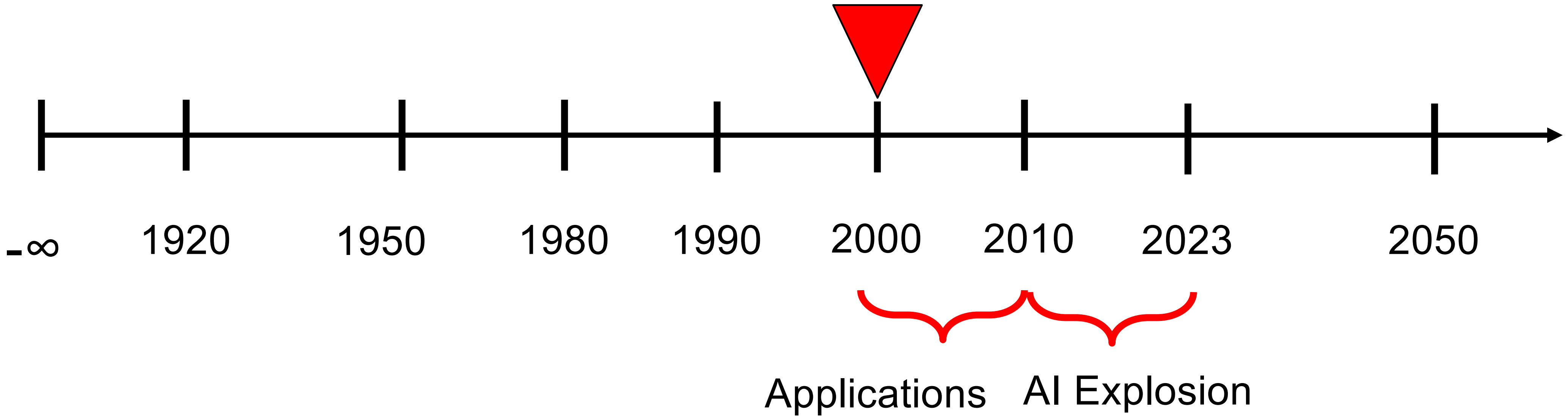
Computer Motion
Zeus robot

Russell Taylor
IBM-JHU

Curexo
Robodoc robot

1980-1990

2000 +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1920
1950
1980
1990
2000
2010
2023
2050
Applications
AI Explosion

Robotics Directions in 2000

Search and Rescue

Drones

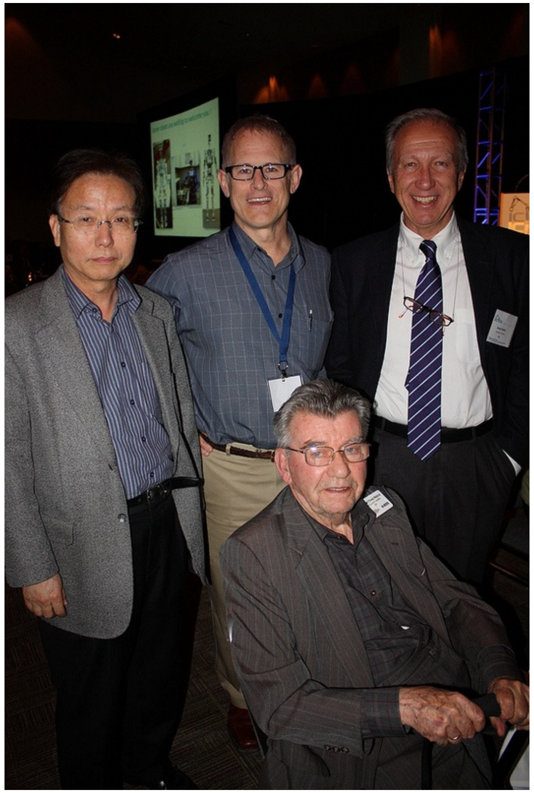
Honda Asimo 2001

Mars Rovers

Inspection

JPL Remains at the Center Stage

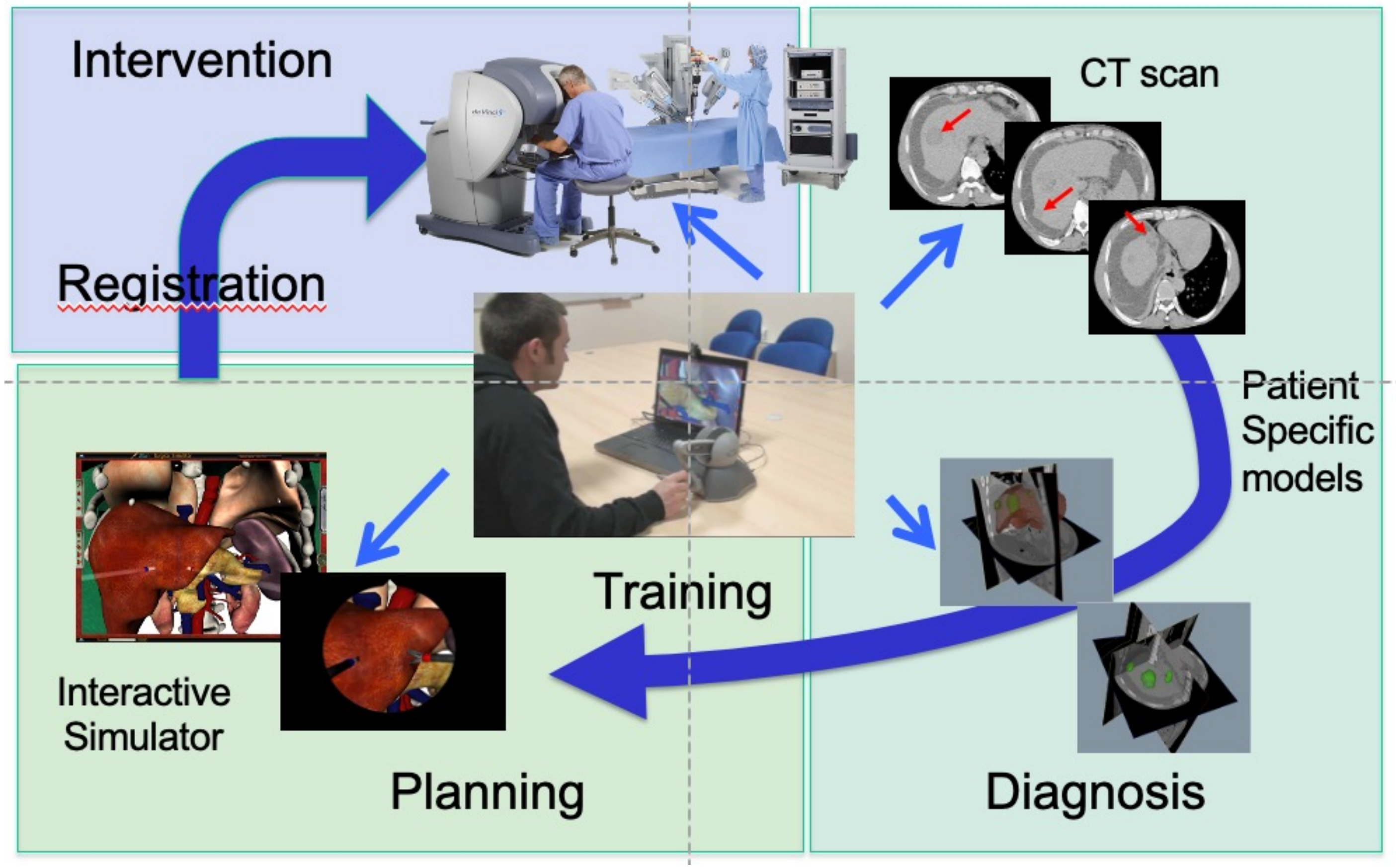
2009



2012

2007

Data-driven Robot Assisted Surgery



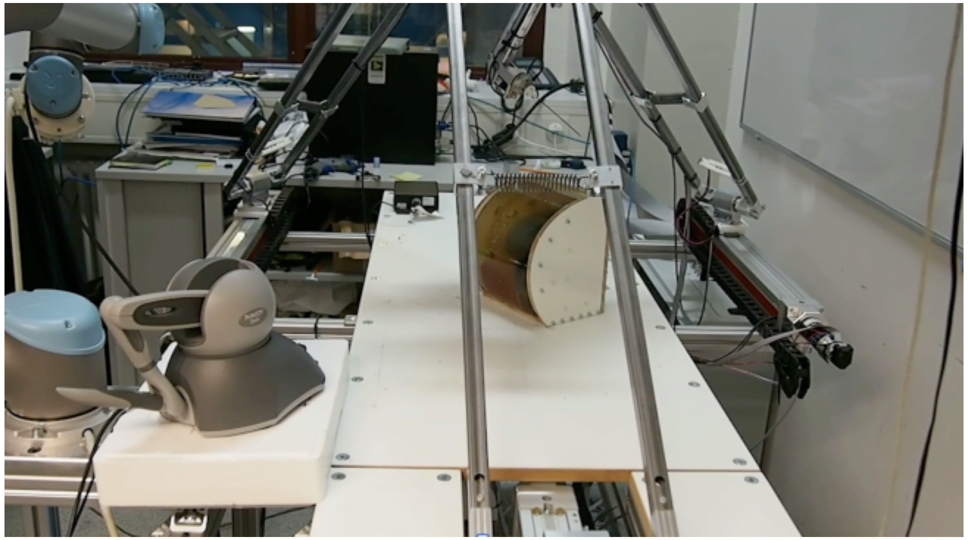
Intelligence and Autonomy

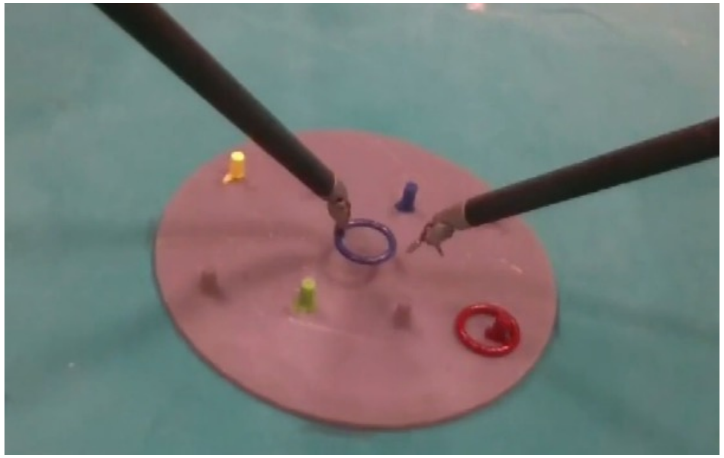
I-Sur INTELLIGENT SURGICAL ROBOTICS

Intelligent Surgical Robotics (2011-2014)

ARS Autonomous Robotic Surgery

erc European Research Council Established by the European Commission



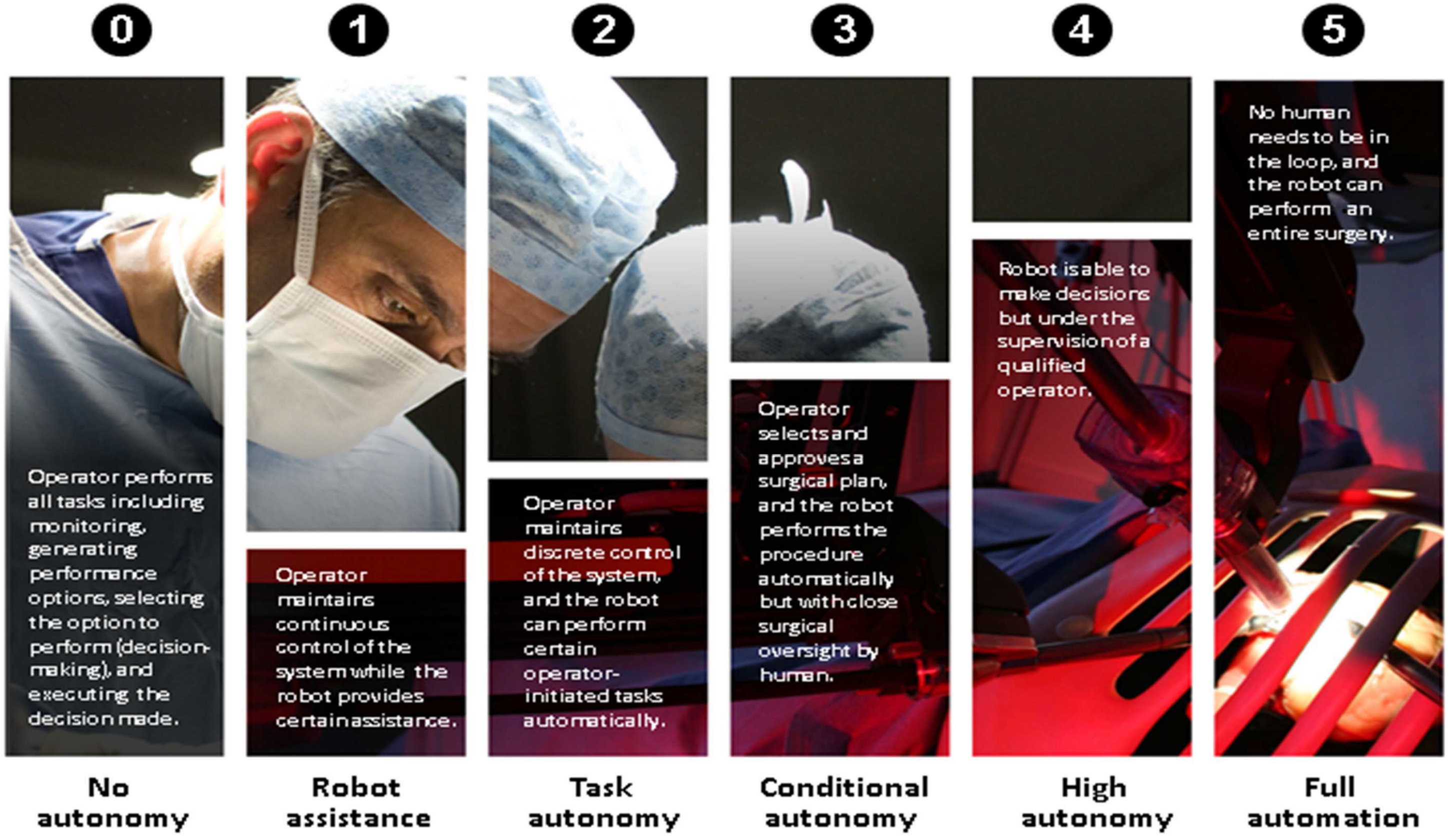


2018-2023

AI + Robotics = Cognitive Robotics

- *Is concerned with endowing a robot with intelligent behavior by providing it with a processing architecture that will allow it to learn and reason about how to behave in response to complex goals in a complex world* (Wikipedia)
- The robot will need to acquire the necessary field-specific knowledge
- The robot will need to know how to plan and carry out a task
- The robot will need to be ”**autonomous**” (within limits)

Levels of Autonomy



Our Projects of Cognitive Robotics

ARS

prost

PROCT

ROBOPSY

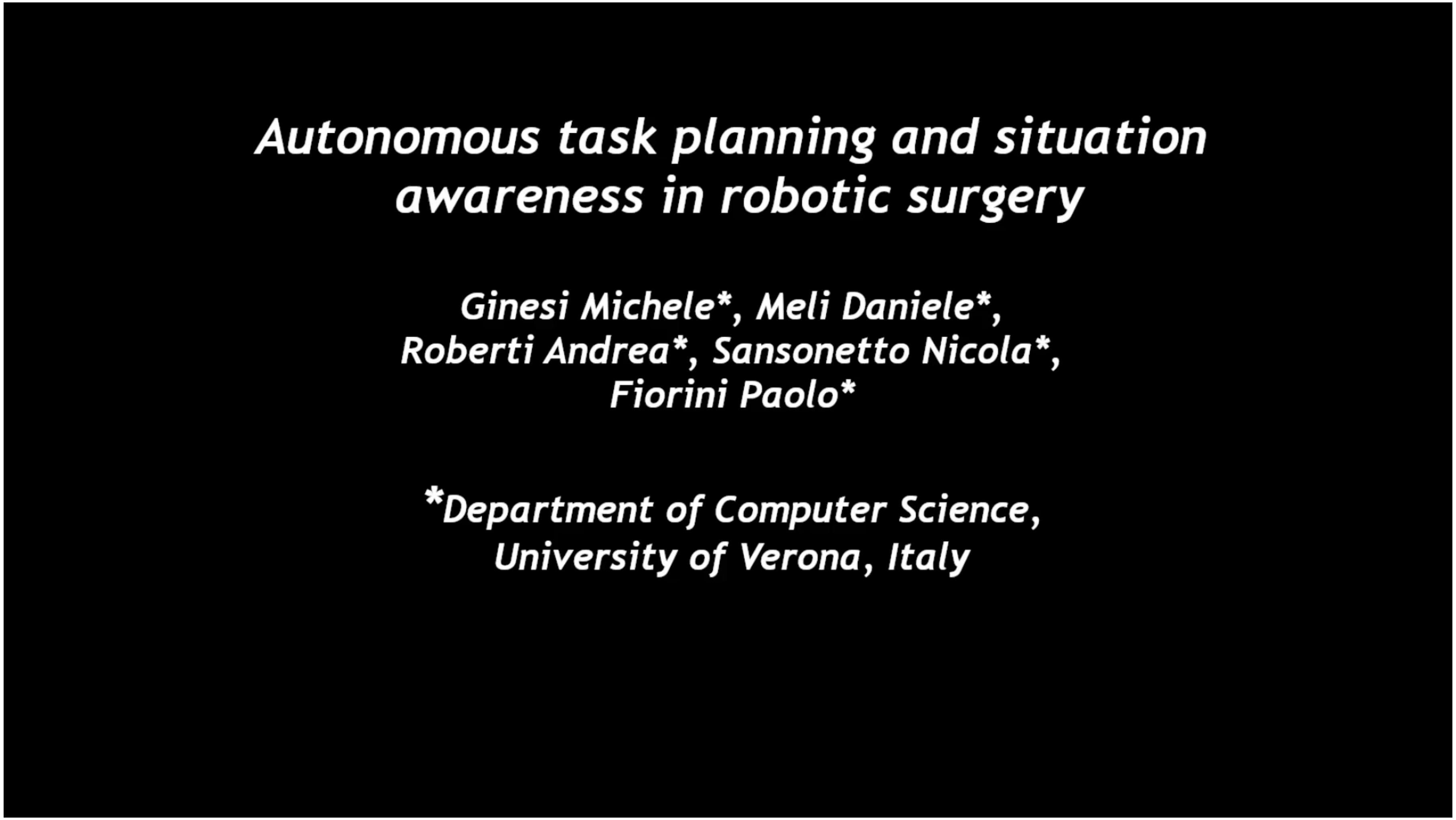
PROFTH

European Research Council
Established by the European Commission

These projects have received funding from the European Research Council (ERC) under the European Union's Horizon 2020 research and innovation programme, grant agreements No. 742671 (ARS) and No. 875523 (PROST)

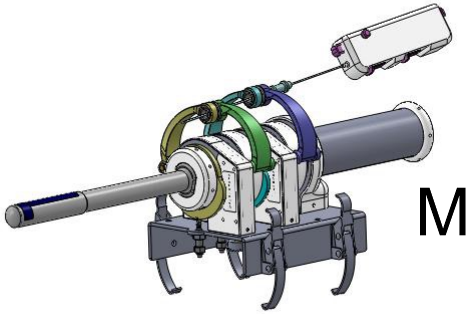
European Innovation Council

Finanziato dall'Unione europea

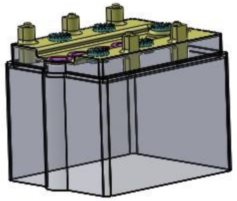


Autonomous task planning and situation awareness in robotic surgery
Ginesi Michele*, Meli Daniele*,
Roberti Andrea*, Sansonetto Nicola*,
Fiorini Paolo*
*Department of Computer Science,
University of Verona, Italy

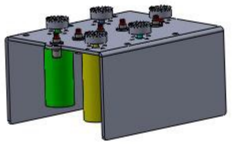
Robot for Prostate Biopsy



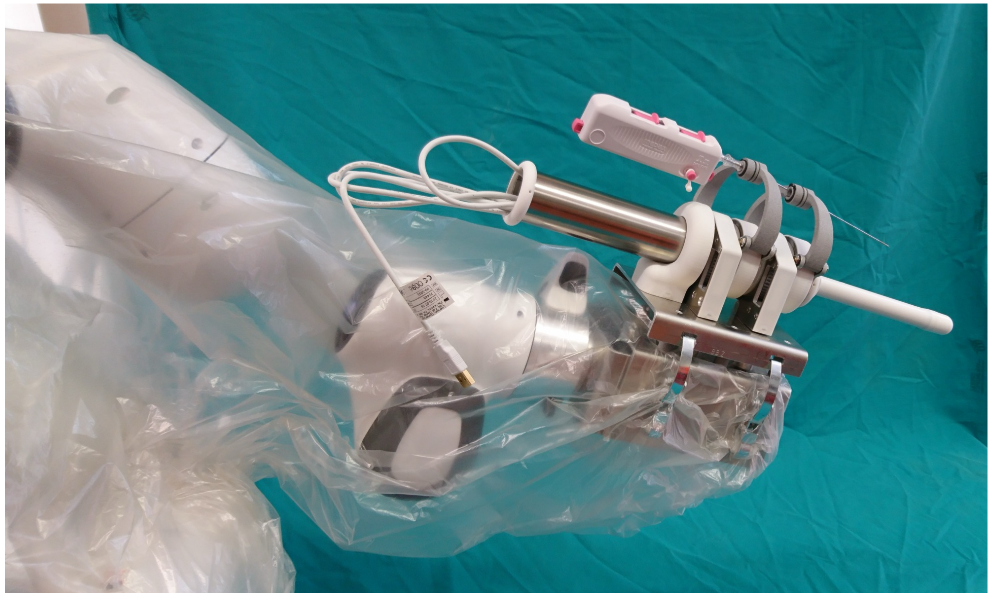
Module for biopsy



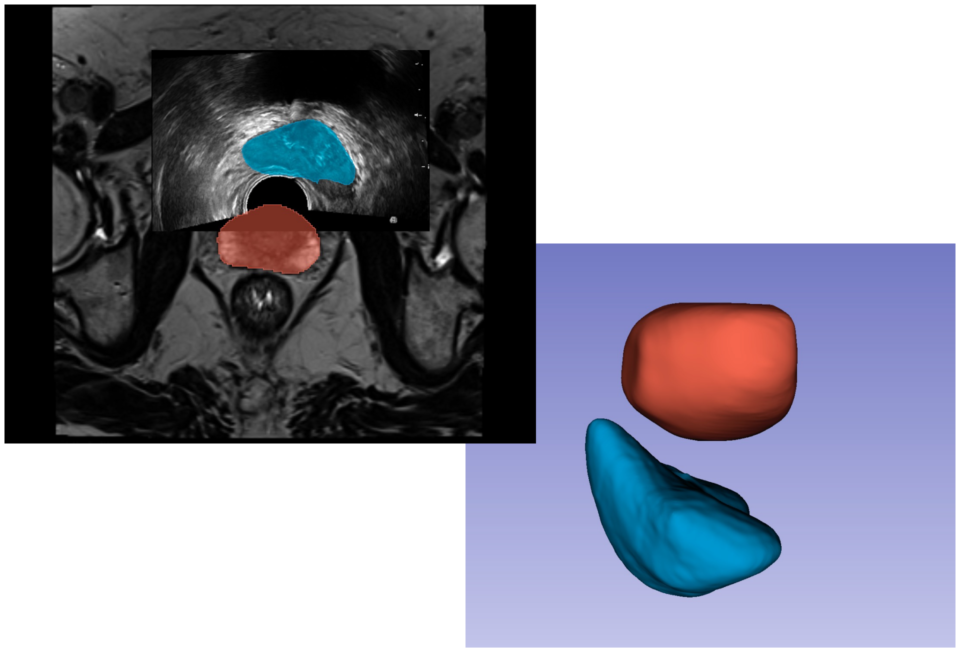
Sterile separation



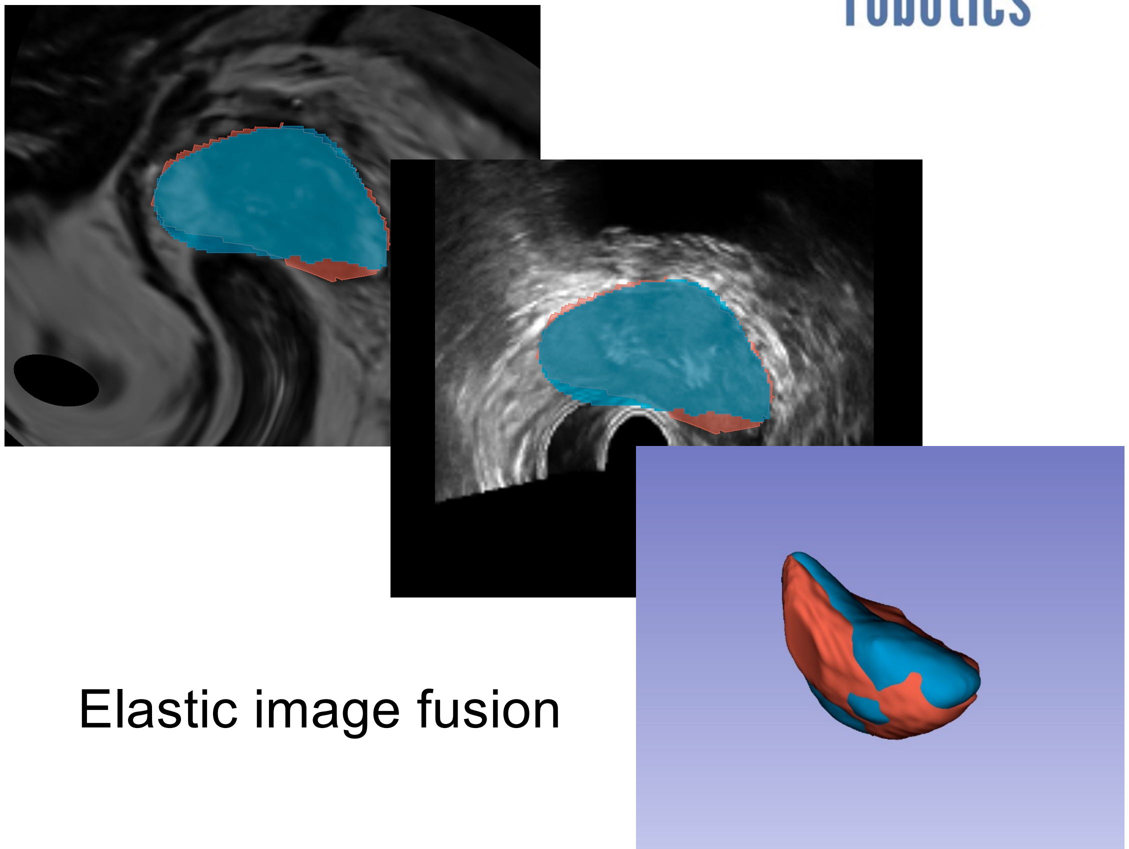
Motors and sensors



Automatic Image Processing and Fusion



The original images: MRI and US



Elastic image fusion

Safety Critical AI Application

- The European Union is discussing, and ready to approve, a regulatory framework for AI applications: the AI Act
- Aims at enforcing AI systems that are (4R):
  - Resilient – fit for its 'intended purpose' (= claimed functionality)
  - Robust – dependable over the course of time (e.g. post market monitoring)
  - Reliable – trustworthy as to design and use,
  - Responsible – preventing or mitigating potential fundamental rights interferences

1. High-risk AI systems shall be designed and developed to include human-machine interface tools,
2. Human oversight shall aim at preventing or minimising the risks to health, safety or fundamental rights

Key Elements of Oversight (from AIA)

To enable human oversight we must ensure that:

a. fully understand the capacities and limitations of the high-risk AI system
b. quickly identify signs of anomalies, dysfunctions and unexpected performance
c. do not be subject to automation bias
d. be able to correctly interpret the high-risk AI system's output
e. be able to decide, in any particular situation, not to use the AI system or its output
f. be able to interrupt the high-risk AI system through a "stop" button or a similar procedure.

=> Natural Language + images are a key element for interpretability and explainability

“The Best Way to Predict the Future is to Create It”

Abraham Lincoln

Road Map Examples

Robotics 2020
Multi-Annual Roadmap

For Robotics in Europe

Horizon 2020 Call ICT-2017 (ICT-25, ICT-27 & ICT-28)

Release B 02/12/2016

SPARC
The Partnership for Robotics in Europe

EFMN
WWW.EFMN.INFO The European Foresight Monitoring Network

Roadmap Robotics for Healthcare

Foresight Brief No. 157

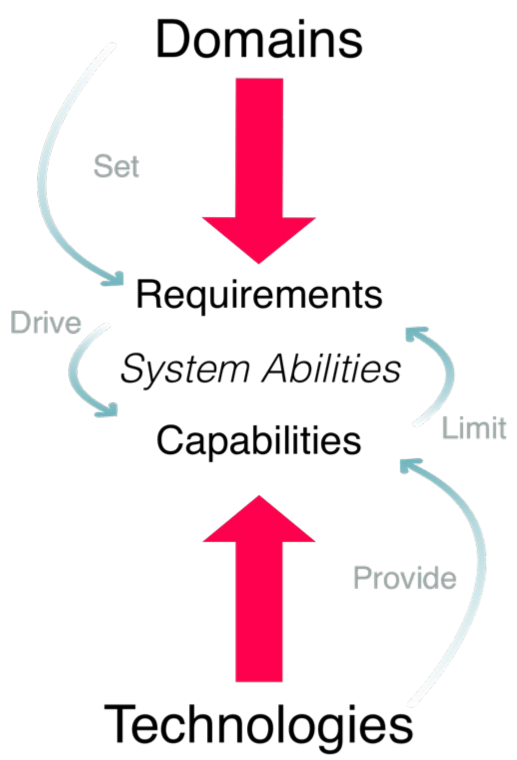
A Robotics Roadmap for Australia 2022

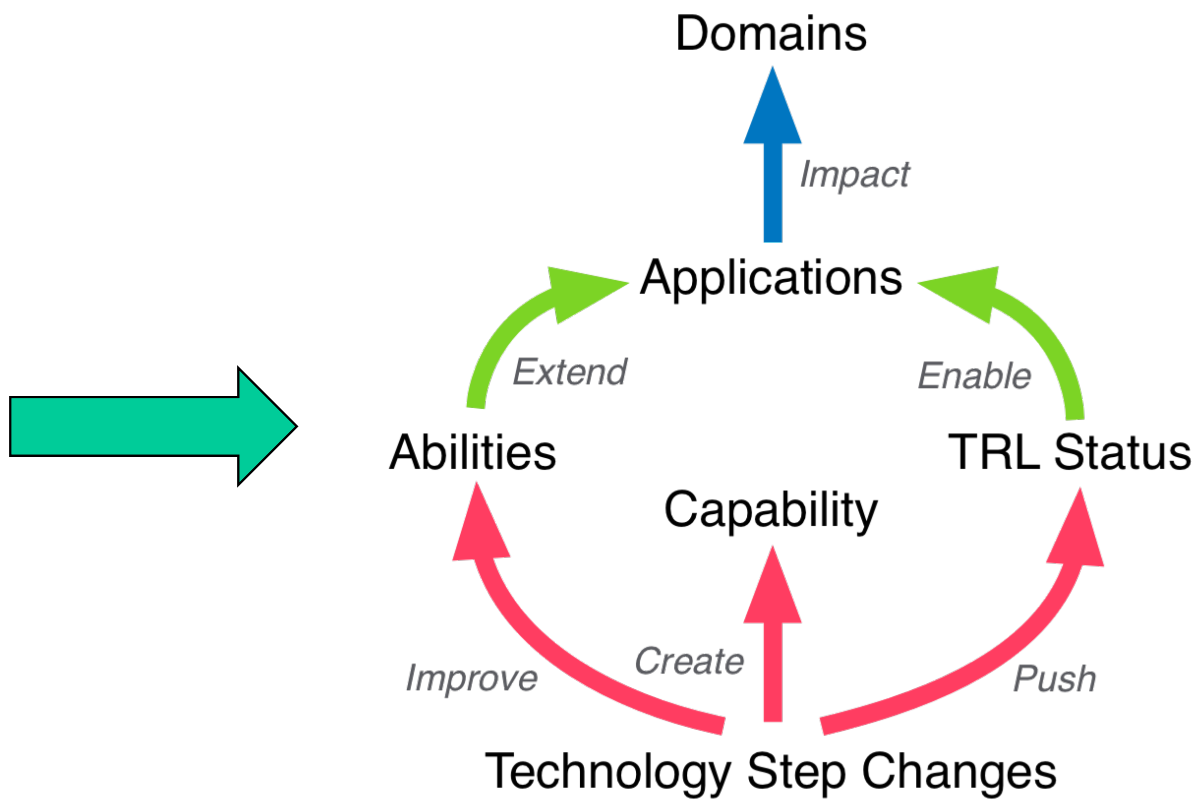
ROBOTICS AUSTRALIA GROUP

Foundations and Trends® in Robotics

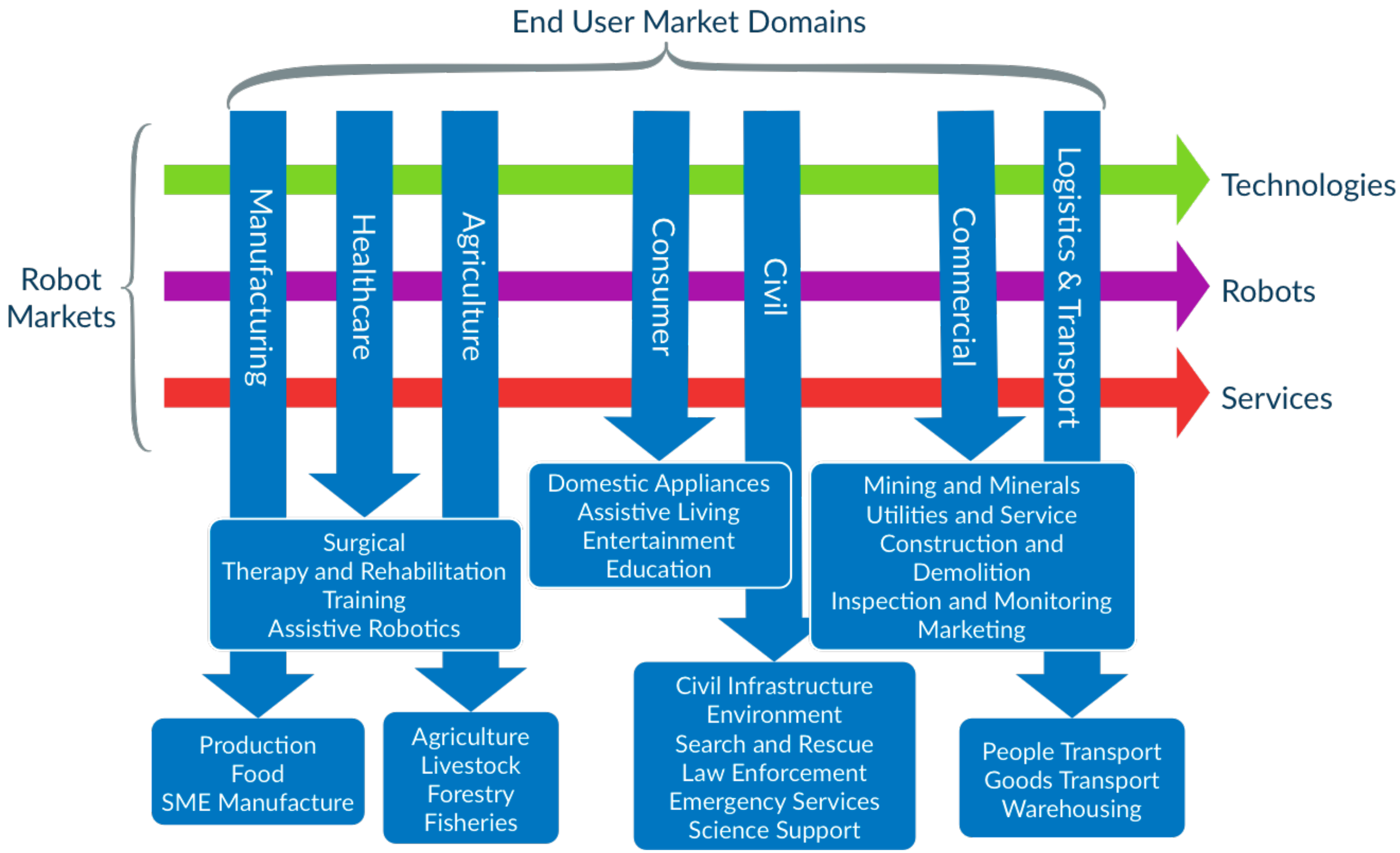
A Roadmap for US Robotics – From Internet to Robotics 2020 Edition

The EU RoadMap: Approach





The EU RoadMap: Domains



Are RoadMaps Effective?

Let's assess the first EU Roadmap of 2004, managed by:

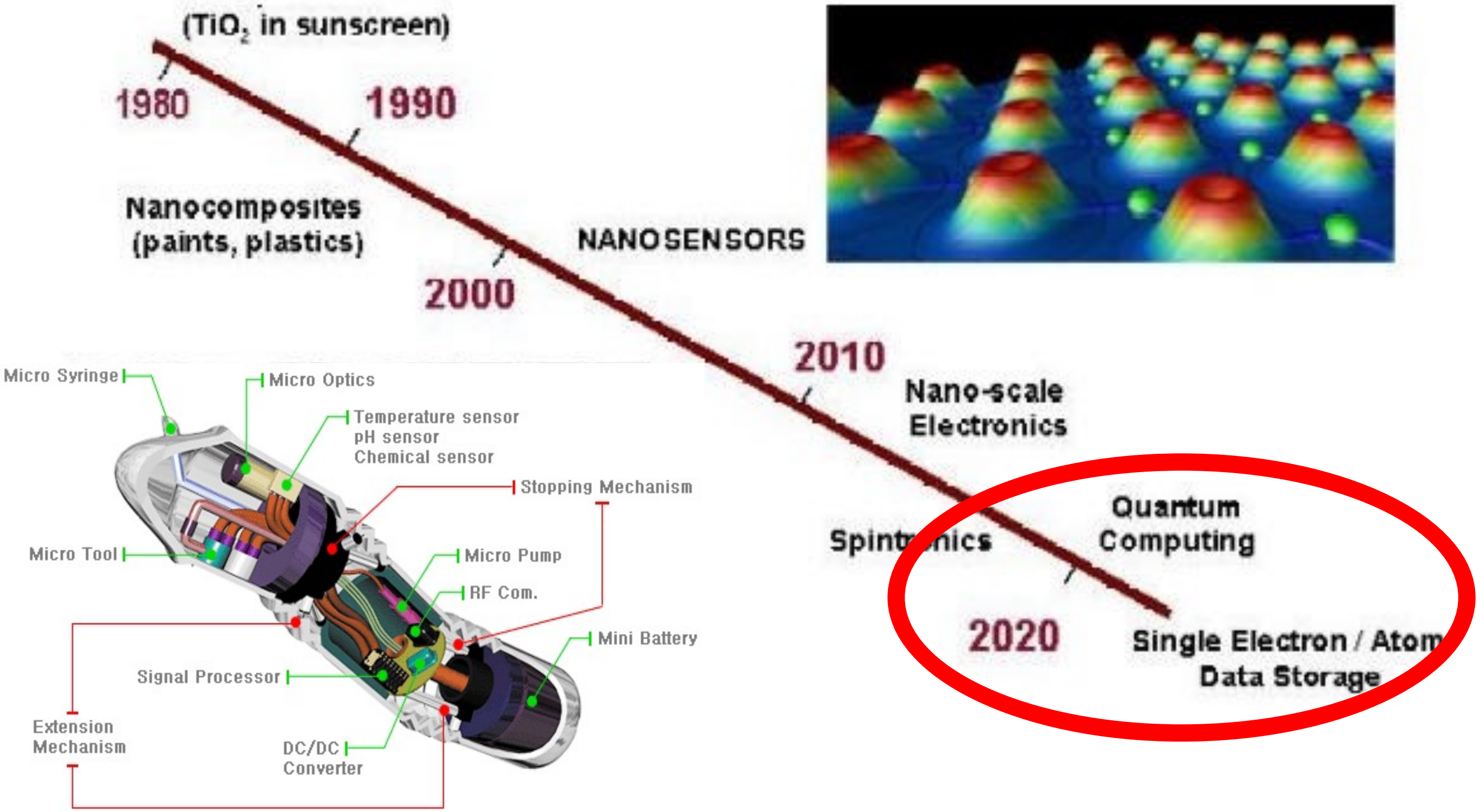
European ROBOTICS Research Network (EURON)

Co-chairs: Prof. Paolo Dario, Scuola Superiore Sant'Anna, Pisa, Italy
Prof. Rüdiger Dillman, Universität Karlsruhe (TH), Germany

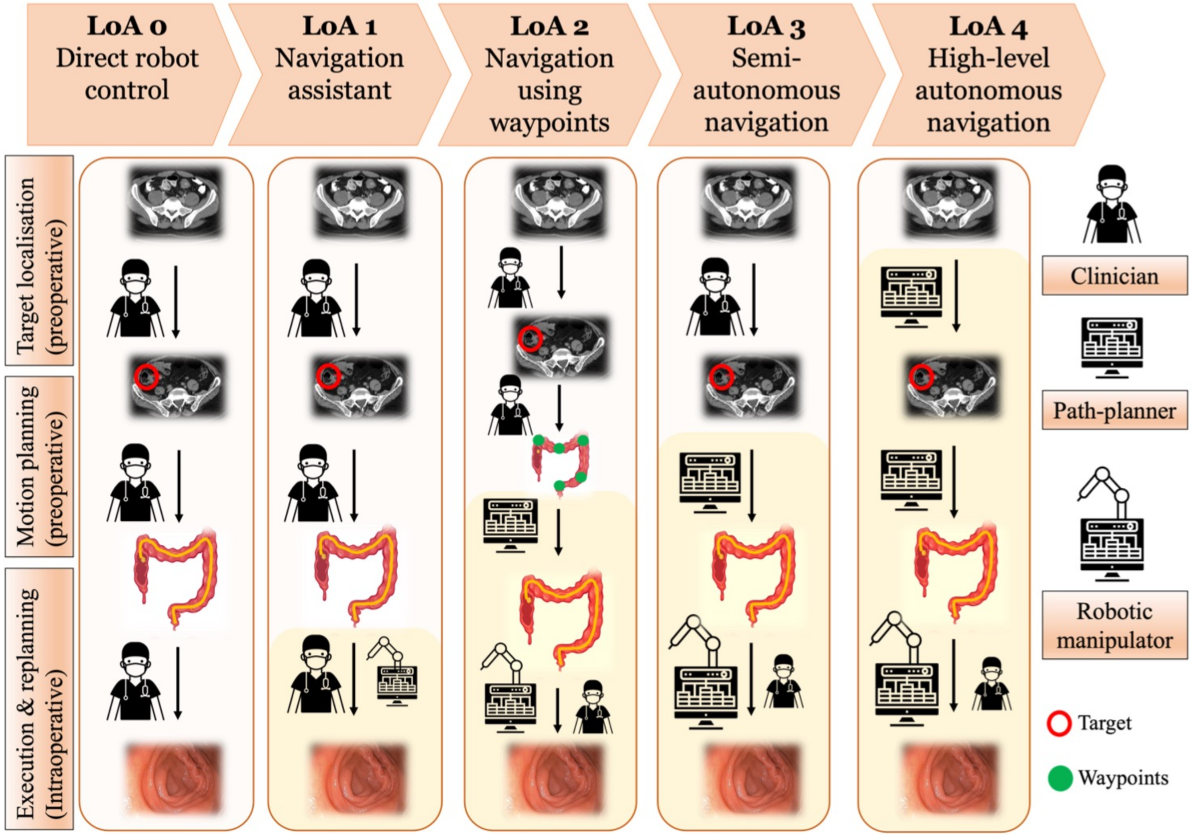
Two case study: Endoscopic Robotic Pills
Humanoid Robots

Endoscopic Robotic Pill: Prediction

- Microactuators, micromechanisms, energy sources
- Vision system
- Telemetric Systems
- Sensor systems
- Control systems, intelligent and autonomous

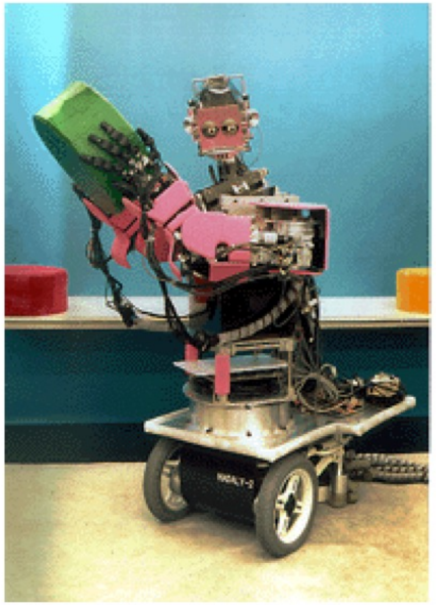


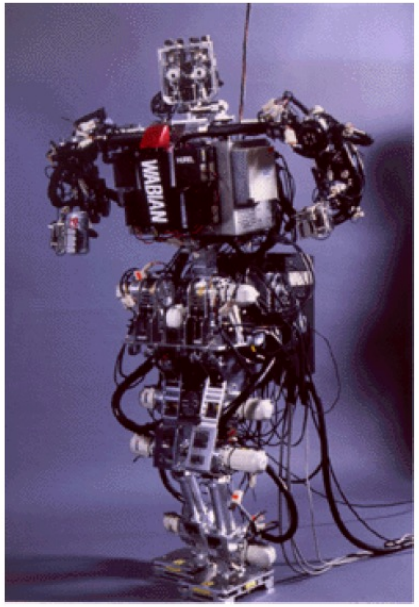
Did not Predict

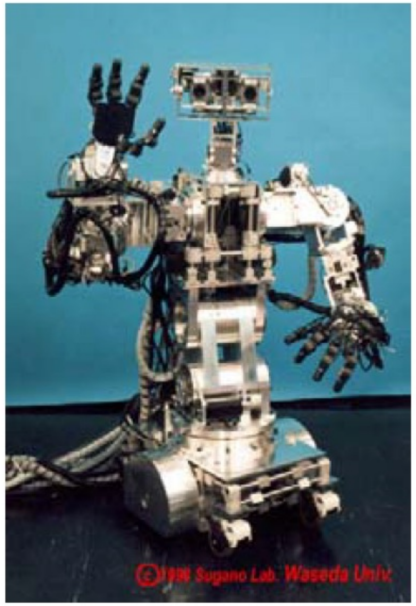


The AI explosion and the development of "traditional" approaches

The Humanoid Robot

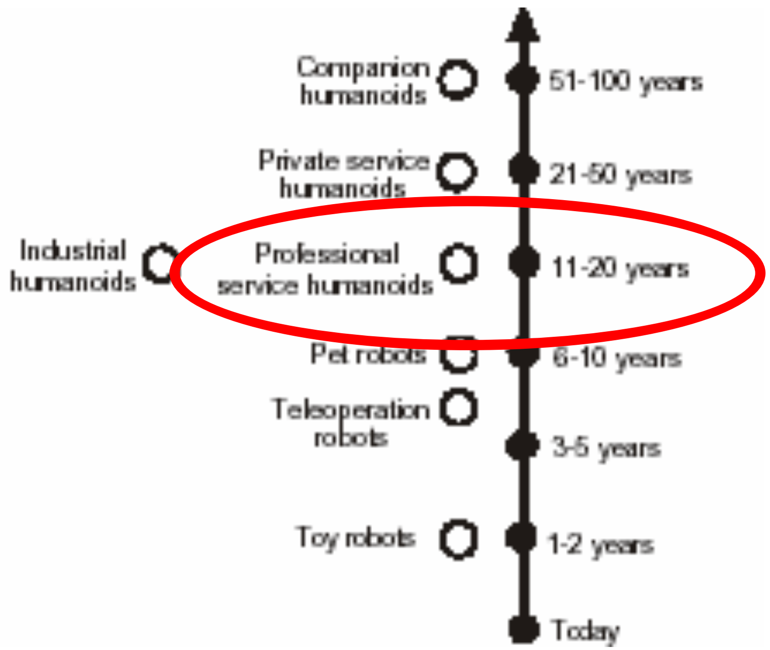


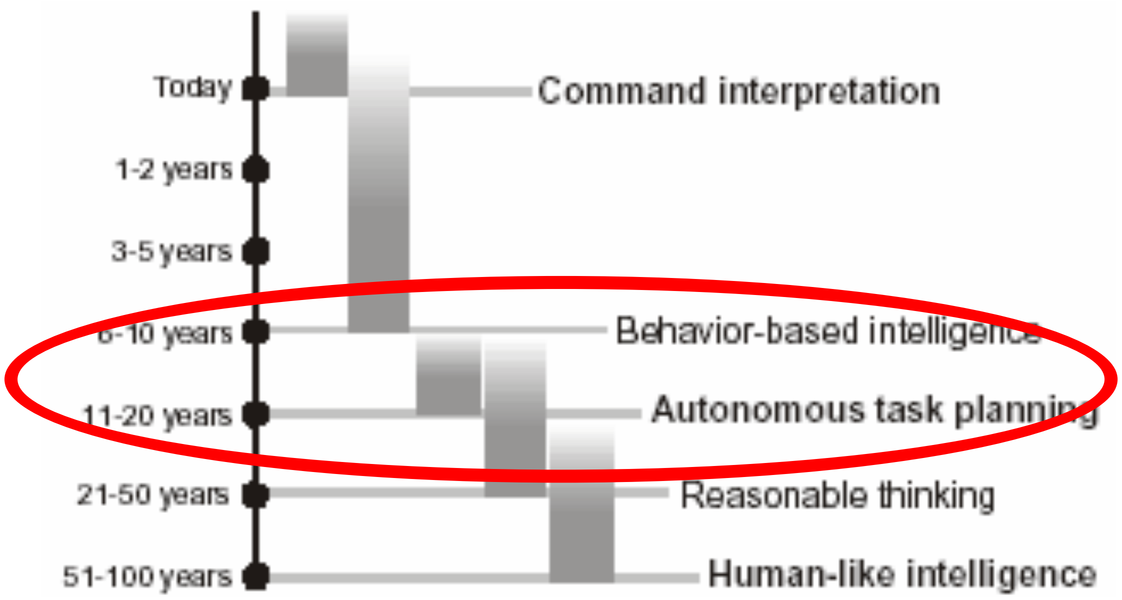




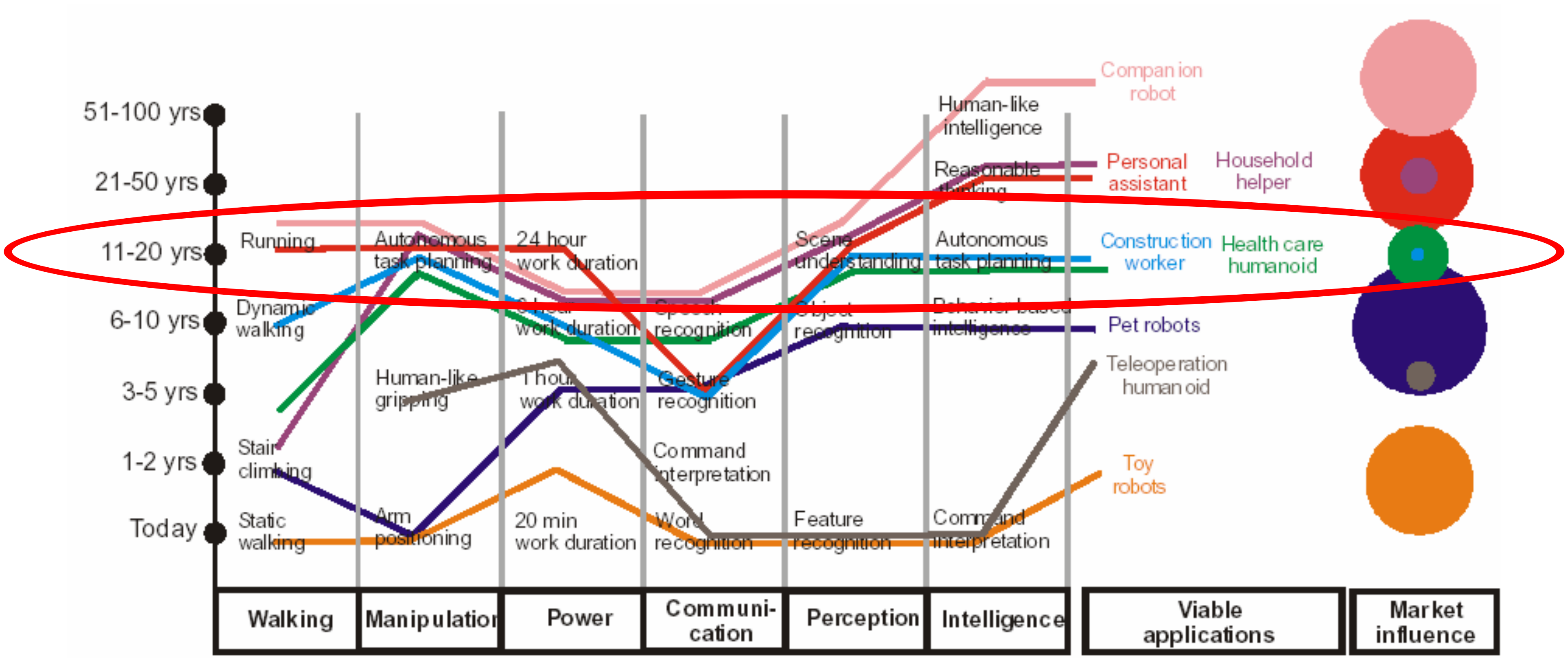
The main development would be in Japan

Predictions on Application





System Prediction

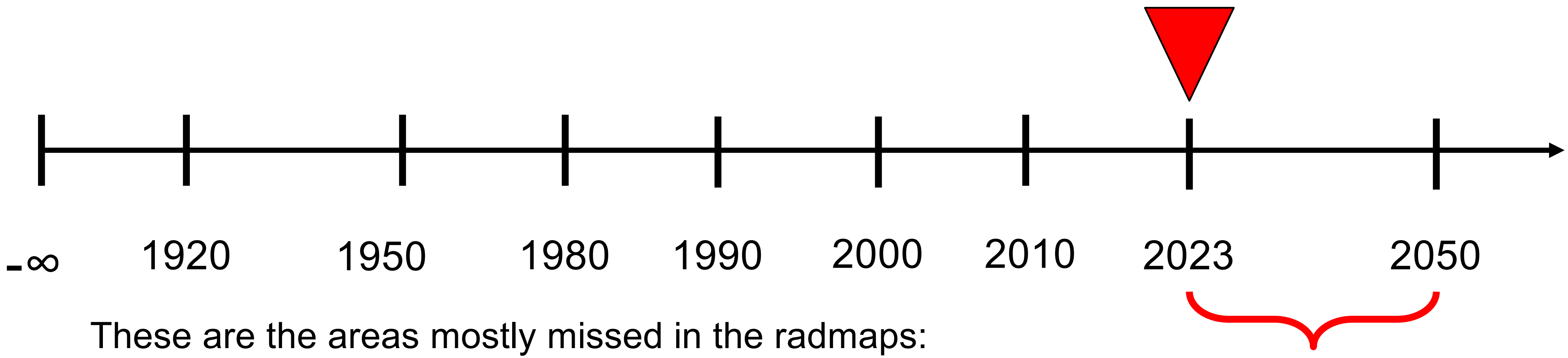


Did not Fully Predict: Mobility and Nation

Tesla

Boston Dynamics

Next Timeline



These are the areas mostly missed in the radmaps:

- Power
- Perception
- Reasoning
- Planning

Out-of-the-box thinking is needed
Must be sensitive to the environment
FRUGAL ROBOTICS is the right approach

What Can We Predict for the Next 25 Years?

Electromechanics:

- Boston Dynamics, Tesla, Intuitive have achieved great results, but the big question is cost: will mass production reduce production costs? probably not if we look ad the car market. We need FRUGAL robots.

Sensors:

- RGBD cameras, Lidar, Hi-Res camera will permit to build very accurate models of the environment… at low cost (see the latest iPhone).

What Can We Predict for the Next 25 Years?

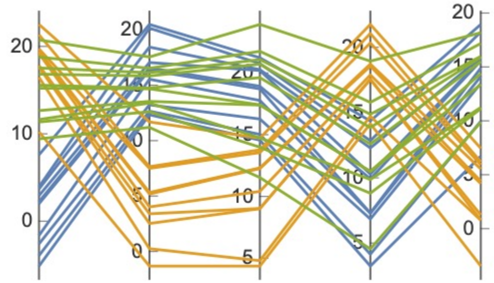
Algorithms:

- Traditional algorithms will return to fashion: the performance of learning approaches and the regulations will limit their applicability => more emphasis on models

AI:

- Will be used when necessary and not everywhere. LLM will not be sustainable and will not be able to address difficult cases. Remember expert systems, there was always a missing conditions. We need simplicity and interpretability.

Conclusions



- It has been very interesting to watch robotics development
- New challenges are waiting:
  - different work styles
  - different research topics
  - more importance to impact of research
  - more emphasis on cost and sustainibility

I hope that in 25 years we will be here to check my forecast !

Inauguration of the Academic Year

Thanks for Your Attention

SEVENTH FRAMEWORK PROGRAMME

HORIZON 2020
LE PROGRAMME DE RECHERCHE ET D'INNOVATION DE L'UNION EUROPÉENNE

erc years
European Research Council